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Technical Efficiency of Sunflower Farmers in Tanzania: Translog Model

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Despite national efforts to promote improved agricultural technologies, such as enhanced seeds and inorganic fertilizers, their effectiveness in Tanzania's central zone remains understudied. This study evaluated the technical efficiency of sunflower farmers in the central zone of Tanzania. It also identified factors affecting their efficiency to offer insights for improving agricultural productivity and supporting sustainable development in the sunflower sector. The study employed a multi-stage sampling technique to select 371 respondents. Data were collected using a structured questionnaire. Descriptive statistics and a stochastic frontier analysis with a Translog production function were used to analyze the data. The Translog production function results showed that sunflower output was significantly influenced by seed quantity ($p<0.001$), farm size ($p<0.001$), and fertilizer amount ($p<0.01$). The inefficiency model revealed that technical inefficiency was significantly affected by age ($p<0.01$), sex ($p<0.05$), education ($p<0.001$), group membership ($p<0.05$), access to credit ($p<0.001$), livestock ownership ($p<0.05$), and extension visits ($p<0.001$). The mean technical efficiency was 60.6%, indicating that, on average, farmers could increase output by 39.4% without employing additional inputs. Efficient techniques and best farming practices including timely sowing, weeding, optimal plant density and appropriate spacing could help achieve this increase. The study offers significant potentials for enhancing sunflower farming productivity in Tanzania's central zone through improved technical efficiency. Policymakers and stakeholders should focus on promote adult education for farmers, improving livestock ownership, increasing access to extension services, encouraging group participation, and enhancing access to credit to boost efficiency and support sustainable development in the sunflower industry.
Keywords: Technical efficiency, stochastic frontier analysis, production efficiency, productivity.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is a globally significant oilseed crop. Ranking third in oilseed production with a 9% share of global output, following soybeans (60%) and rapeseed (12%) (Pilorgé, 2020). In vegetable oil production, sunflower oil accounts for 9.2% of the global supply, placing it fourth behind palm oil (36.5%), soybean oil (27.4%), and rapeseed oil (12.5%) (Inovia & Brétignières, 2020). The Russian Federation (25%), Ukraine (22%), and Argentina (18%) are the leading global sunflower seed producers (Kombe, *et al*., 2017; Liampawe, 2019; Njiku & Nyamsogoro, 2019). These countries utilize extensive, mechanized agricultural systems, supported by substantial capital investment and access to critical resources. Europe accounts for 73% of global sunflower production, followed by Asia (12.1%), America (9.9%), and Africa (4.9%) (Elena *et al*., 2022). The crop's versatility supports its use in edible oil, biofuel, animal feed, and rubber production, underscoring its economic importance worldwide (Chappa, 2022; Kombe *et al*., 2017; Kottapalli *et al*., 2020). In Tanzania, sunflower is the leading edible oil crop, supplying 65.5% of local edible oil and 40% of national cooking oil demand (Kingu *et al*., 2024; Mwatawala *et al*., 2022). Cultivated on approximately 6% of Tanzania's arable land, sunflower is primarily small-scale, rain-fed, and intercropped with staple crops (Kombe *et al*., 2017). Sunflower's drought tolerance and adaptability make it well-suited for arid and semi-arid regions, particularly in Tanzania's central zone, improving its agricultural viability (Kingu *et al*., 2024; Lyanga, 2024). Tanzania ranks 11th globally and second in Africa after South Africa, accounting for 2.4% of global and 35% of African sunflower seed production (FAOSTAT, 2021). Smallholder farmers and small- to medium-sized processors rely heavily on the sunflower subsector, which has the potential to drive

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industrialization and economic development (Njiku, 2019; Zeng, 2016).

Despite its importance, sunflower farming in the country faces major obstacles leading to low productivity. Previous studies have reported yields of 0.4 to 1 ton per acre, which is far below the potential yield of 2-3 tons per acre (Kombe *et al*., 2017; Mwatawala *et al*., 2022; URT, 2021). The country's domestic edible oil production meets only 40% of the national demand, which is growing at 3% per year, with imports filling the remaining gap (HAPA, 2022; Mpenda & Mgeni, 2021). Challenges contributing to low productivity include reliance on traditional farming methods, rain-fed systems, limited access to modern inputs, and inefficiency (technical inefficiency) in production process (Chappa, 2022; Kingu *et al*., 2024). These challenges hinder the country's ability to exploit its expansive arable land and favorable agroecological conditions to close the edible oil demand gap through domestic production. Technical efficiency (TE), the ability to maximize output from a given set of inputs under existing technology, is critical for enhancing sunflower productivity (FAO, 2017). Improving technical efficient allows agricultural expansion without additional resources, making it more relevant for resource-constrained smallholder farmers. (Shamsudeen *et al*., 2017). Efficiency analysis provides valuable insights for policymakers to optimize resource allocation and improve productivity among smallholder farmers (Abate *et al*., 2019). Socio-economic factors (e.g., education), institutional factors (e.g., extension services), and farm specific characteristics (e.g., farm size) significantly affect farmers' efficiency, promoting improved adoption of innovative practices and technologies (Bedasa & Tekalign, 2023; Ebukiba *et al*., 2020). Inefficient resource use undermines productivity, and introducing modern technologies without addressing inefficiencies may yield suboptimal results (Bati & Haji, 2020; Tumuri *et al*., 2024). Thus, enhancing TE is essential for improving food security, reducing poverty, and fostering sustainable agricultural growth. Recognizing the importance of sunflower production, the Tanzanian government has prioritized improving its productivity to enhance rural development, increase income, and reduce poverty (George, 2020). Despite favorable conditions and rising demand, productivity remains below potential. This study therefore aims to assess the technical efficiency of sunflower production and identify its key determinants in the Central Zone of Tanzania.

MATERIALS AND METHODS

***Study area*:** The study was carried out in Dodoma and Singida regions, which account for 53.8% of Tanzania's total sunflower production (URT, 2021). One district was purposively selected from each region. These are Kongwa district from Dodoma and Iramba district from Singida region. Kongwa district lies between latitude 5° 30' to 6° 00' South and longitudes 36°15' to 36°00' East of Greenwich Meridian, with an altitude ranging from 900 to 1000 meters above sea level. Iramba district covers 4,549.40 square km located between latitudes 4º to 4º.3º South and longitudes 34º to 35° east. The district is bordered to the northwest by the Shinyanga region, to the north by Simiyu Region, to the east by the Mkalama district, to the south by Ikungi district and to the west by the Tabora region.

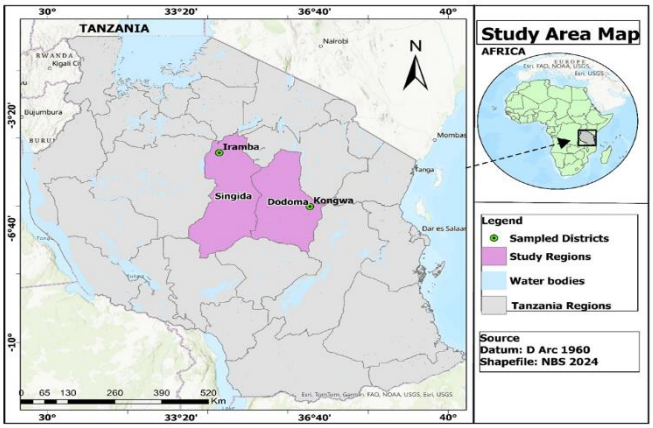

Figure 1. Map of the study area.

***Sampling, sample distribution*:** This study employed a multistage purposive sampling method involving two stages. Initially, Iramba and Kongwa districts were purposefully selected. In the second stage, two wards from each district—Shellui and Kinampanda from Iramba, and Mtanana and Ngomai from Kongwa—were purposively selected. Four villages, one from each ward (Mtanana and Saigon from Mtanana and Ngomai, respectively; Nselembwe and Kyalosangi from Shellui and Kinampanda, respectively), were then selected using a simple random sampling technique. The sampling frame was established using village registers of sunflower-farming households as follows: Kyalosangi (992) and Mtanana (939) and Nselembwe (1870), and Ngomai (1281). The sampling frame is created by this total (5082). Finally, from this frame, households were selected using simple random sampling based on the Yamane formula to determine the final sample size as follows:

$$n = \frac{N}{1+N(e)^2} \qquad (1)$$

Where: n=the sample size

N = the population size (992+939+1870+1281) = 5082

e =is the level of precision (0.05)

Therefore;

$$n = \frac{5082}{1+5082\ (0.05)2} = 370.795 \approx 371$$

The sample size for this study was 371 household heads.

The sample size was used to compute the proportion of households in all study villages using the number of households in each village. The Pandey & Verma (2008),

formula was used in order to draw the proportional sample per village as follows:

$$n_h = \frac{N_h'}{N} \times n \qquad (2)$$

Whereby; n_h= subsample (1, 2, 3…) for each stratum e.g., village1; N_h = sub-sampling frame (Total number of households in the study villages); n = desired sample (total number of farmers' households in the study); N = Total population.

The distribution is as indicated in Table 1.

Table 1. Specified villages involved in the study.

District	Ward	Village	Households
Kongwa district	Mtanana	Mtanana	69
	Ngomai	Saigon	93
Iramba district	Shellui	Nselembwe	137
	Kinampanda	Kyalosangi	72
Total			371

***Theoretical framework*:** This study was guided by the theory of production efficiency, which can be explained in three ways that are used to measure the level of efficiency in production. These include economic efficiency, technical efficiency and allocative efficiency. Technical efficiency of production is the ability of a firm e.g., sunflower farm to create a maximum level of output from a given level of inputs. Technically efficient firms are those firms that are operating on the production frontier that represents the maximum output attainable from each input level (Miho, 2018; Tumuri *et al*., 2024). Allocative efficiency also termed as price efficiency in the work of Farrell, is the ability of a firm to use inputs in optimal proportions, given their respective prices and available technology (Tumuri *et al*., 2024). Economic efficiency explains farmer's ability to produce optimal output with minimum cost given technology available at their disposal.

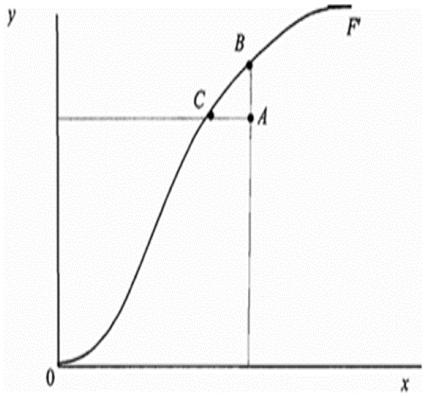

Figure 2. Production/technical efficiency on the frontier.

Theory of production efficiency is described graphically using the production frontier which explains maximum feasible output given input level. Technical efficiency in production is achieved when a farmer operates on the production frontier, while production inefficiency occurs when the farmer operates below this efficient boundary. Production efficiency is presented by point 'B' and 'C' in figure 1 that are points of technical efficient as production lies on the frontier line (OF′). Divergent of production from the frontier line of best production indicates production inefficiency. Technical inefficiency at point A proves possibility of increasing output production to its maximum using the same level of inputs used by producer at point B (Miho, 2018).

***Data collection and data analysis*:** A survey method was adopted in this study for the collection of primary data. A structured questionnaire was prepared as a tool to collect data such as quantities, prices, and yields from the respondents. This study employed the stochastic frontier analysis (SFA) model to estimate the technical efficiency (TE). Stochastic Frontier Analysis (SFA) is one of the most widely applied parametric approaches that follows a defined production function (Hailekiros *et al*., 2018) . The model was developed initially by (Aigner *et al*., 1977). In the stochastic frontier framework, the production analysis is done in two stages. In the first, the frontier model is used to estimate by maximum likelihood while in the second stage the estimated model is used to identify inefficiency measures (Ng'Atigwa *et al*., 2022)

The SFA approach offers some sensible advantages over the other methods that are usually used in efficiency analysis (Bati & Haji, 2020). Most importantly, the model is more preferred because it decompose the error term into two, according to sources. The component that incorporates inefficiency due to unobserved factors beyond the farmer's control and the error component depicting technical efficiency relative to the stochastic frontier. Besides, it is appropriate to measure the relationship between multiple input and a single output variables (Endalew *et al*., 2023). Agriculture production in most African countries, like Tanzania, is typically rain-fed, which makes them vulnerable to weather shocks, pests, and diseases. Ignoring this could cause this study to produce skewed estimates. Stochastic frontier analysis (SFA) was employed in this study to measure the technical efficiency (TE) of sunflower farmers in Tanzania's central zone corridor. SFA was selected for its ability to identify and separate two distinct types of inefficiencies when farmers deviate from the production frontier (Miho, 2018). Employing SFA approach, the maximum level of output that can be achieved from a given input level is determined by a production function. This describes the technical relationship between inputs and outputs of a production process. Stochastic production frontier is specified as:

$$\text{Yi} = Xi\beta + vi - ui$$

Where; Y_i is the sunflower output, X_i is the vector of explanatory variables and control variables and β is the vector of parameters while V_i and Ui are the component error terms. V_i is a symmetric error term represents variations due to measurement errors and factors beyond the farmer's control which follows normal distribution; $vi \sim N(0, \sigma_i$

U_i is a non-negative measure of technical inefficiency relative to the stochastic frontier and is truncated normally distributed. The Translog production function (TLPF) was then used in this model to measure technical efficiency (TE). The TLPF model considers that there is a linear and nonlinear relationship between the inputs and the outputs and that the production elasticities are not constant (Berndt & Christensen, 1973). The Translog Production Frontier (TLPF) model used to estimate technical efficiency incorporates four key factors: labor cost, seed quantity, farm size, and fertilizer amount. The model specified as:

$\ln(Yi) = \beta_{0+}\beta_1 \ln(\text{Land-L}) + \beta_2\ln(\text{Labor-LB}) + \beta_3 \ln(\text{Seeds-S}) + \beta_4 \ln(\text{Fertilizer-F}) + \beta_5\ln(\text{Labor})^2 + \beta_6 \ln(\text{Fertilizer})^2 + \beta_7 \ln(\text{land})^2 + \beta_8(\text{seeds})^2 + \beta \ln(\text{Land x labor}) + \beta_{10}\ln(\text{Land x fertilizer}) + \beta_{11} \ln(\text{Seeds x fertilizer}) + (v_i - u_i)$

Where: $\ln Y_i$ is the natural log of total quantity of sunflower in kg, L-is the total land size planted in acres, LB-represent total labour cost incurred in production (TZS), F-quantity of fertilizer used in farming season (Kg), S-quantity of seeds (Kg) used in a farming season, β s is unknown parameters to be estimated while v_i is a random error which is associated with random factors outside the control of farmers, such as weather and disease) and μ_i random error for technical inefficiency component.

Then, the stochastic frontier estimation then estimates a second function that connects the inefficiency measured in the first stage using the explanatory variables that relate to socio-economic, farm, and institutional features. The inefficiency equation is written as:

$$U_i = X_i\delta + Z_i$$

Where: X_i is the vector of factors (explanatory) affecting technical inefficiency of the i-th observation and δ represents parameters while Z_i is the error term.

RESULTS AND DISCUSSION

***Socio-economic characteristics*:** This section describes socioeconomic factors that influence individuals and groups within a society, affecting their access to resources, opportunities, and quality of life. These factors include age, experience, education, marital status, gender, family size, farm size under sunflower, number of plots owned, owned livestock, access to extension services, participation in farmers' groups and access to credits.

Table 2 findings revealed that, the mean age for the sunflower farming household is 44.7 years from the pooled sample with the minimum of 20 years and maximum of 90 years. Similar findings were obtained across the districts, where the mean age 54.4 and 46.2 years were reported from Iramba and Kongwa districts, respectively. This suggests that the majority of sunflower farmers in the study area are older households with potential experience and control over resources. The pooled sample showed that the average number of years spent in school was 7.8 years, with 8.6 years in Iramba and 7.1 years in Kongwa district. The majority of households surveyed had only achieved primary school education, which represents the lower level of formal education. This lower educational background is likely to contribute to lower productivity among these households. This finding is in line with Mwatawala *et al.* (2022) who found that 73.9% of the surveyed sunflower farmers in Chemba district attained primary education. The mean years of experience in the pooled sample is 10.6, with 11.7 years in Iramba and 10.7 years in Kongwa. Farmers with more experience are typically expected to perform better than those with less experience, as experience is a crucial component of business planning and forecasting. The pooled sample received an average of 1.7

Table 2. Socio-economic characteristics.

Variables	Pooled sample			Iramba district			Kongwa district		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Age	44.70	20	90	45.40	21	90	46.20	21	86
Experience	10.60	1	50	11.70	1	50	10.70	3	35
Education (Years)	7.80	0	16	8.60	0	16	6.70	0	14
Household size	4.30	1	13	4.20	1	10	4.20	1	12
Farm-size (acres)	7.30	1	40	7.10	1	35	7.10	1	38
No. plots	1.80	0	5	1.60	0	5	1.90	1	3
Ext-visits	1.70	0	5	2.10	0	4	1.90	0	4
Sex	0.74	0	1	0.68	0	1	0.61	0	1
Marital status	0.79	0	1	0.82	0	1	0.77	0	1
Group membership	0.28	0	1	0.36	0	1	0.14	0	1
Credit access	0.30	0	1	0.34	0	1	0.30	0	1
Own livestock	0.78	6	57	0.84	12	57	0.79	4	36

extension visits every farming season, compared to 2.1 in Iramba district and 1.9 in Kongwa district. Extension services facilitate the communication of innovations to farmers and can help farmers in implementing suitable measures in place particularly during periods of stress incidence i.e pests and disease outbreaks. This finding is supported by the study of Ahiale *et al*. (2019) on technical efficiency of broiler production in Ghana, which discovered that an average of two extension visits were received during a production season.

Based on Table 2, the results showed that 74% of the sampled sunflower farmers were male, while 26% were female. Comparable patterns were observed in the surveyed districts: in Kongwa, 61% of the sampled farmers were male and 39% were female, whereas in Iramba, 68% were male and 32% were female. The results suggest that males dominate sunflower production. This finding is in line with Zozimo *et al*. (2023), who found that 84.6% were males involved in interventions for enhancing technical efficiency of sunflower producers in Uganda. In addition, it was discovered that 78.2% of the pooled sample had owned livestock. Similar results were reported in Iramba and Kongwa districts, with 83.5% and 79.4% of households reporting livestock ownership, respectively. Farming households can use livestock for a variety of economic purposes. These include serving as a source of draught power, providing an alternative means of financing input costs, and supplying manure as a substitute for fertilizer. Approximately 30.2% of respondents in the pooled sample were credit users, with similar findings in Iramba district (33.5%) and Kongwa district (29.8%) used credit in sunflower production. Credit enhances farmers' ability to finance their purchase of modern technology under cash constraints, thus paves the way for timely deployment of modern farm inputs. Similar results were found by Endalew *et al*. (2023), where 33.2% of wheat smallholder famers used credit in Northwestern Ethiopia. About 28% of the pooled sample respondents reported to participate in various farmers' groups in the study area. Participation in farmers' groups can improve agricultural productivity and efficiency through access to more technical information. In line to Ghimirea *et al*. (2023) observed that around 51.8% of lentil farmers in Nepal were members of several farmers' groups and cooperatives.

Estimation of stochastic production frontier models

***Model performance*:** The overall model performance was satisfactory (Table 3). The Wald chi-square of overall model significance had a critical value of 21.16 % at a 1% significance level. The variance parameter of the frontier model shows that 31.1% of the variation of the value of output were caused by factors beyond the control of the farmers. In contrast, 69.6% of output variations were associated with the technical inefficient. Moreover, the inefficiency ratio λ (lambda) is 2.4227. This means that the variance in inefficiency is more than twice that of stochastic noise, suggesting that inefficiency is a dominant contributor to output variability.

***Maximum likelihood estimation*:** Table 3 presents the results of the maximum likelihood estimation of the stochastic frontier production functions. The functions are for sunflower production in two districts in the central zone corridor of Tanzania. Pooled sample results revealed that land, seeds, and fertilizer are regarded as predictors of sunflower yield in the central zone of Tanzania. These factors were found to have a substantial impact on sunflower production. Land and seeds were found to have a positive correlation with sunflower yield at the 1% level of significance, whereas fertilizer was found to be significant at the 10% level. This suggests that, for every 1% increase in land size and seed quantity, sunflower production will increase by 4.19% and 5.13%, respectively. Likewise, sunflower production will also rise by 3.57% with a 10% increase in fertilizer quantity. This demonstrates the significance of land, seeds and fertilizer as the main inputs in any process involving agricultural production. The combined effect of fertilizer reported to have a negative correlation on sunflower output at 5% significance level. This suggests that doubling fertilizer use would lead to decrease of sunflower output by 2.84%. Double fertilizer treatment resulted in a decreased yield for sunflower production. This is because rainfall in Tanzania's central zone corridor is unpredictable and typically deviates from the optimum level amount. Increased fertilizer uses with unpredictable rains caused field crops burns and had a detrimental effect on crop yield. On the other hand, the interaction coefficient between sunflower seeds and fertilizers was positive and significant at 5% significance level. The complementary relationship between sunflower seeds and fertilizer accounts for their positive correlation. Consequently, sunflower production could be significantly improved by properly timing fertilizer applications and using the optimal amount of sunflower seeds. Yami *et al*. (2013) found similar results when they investigated sources of technical inefficiency of smallholder wheat farmers in selected waterlogged areas of Ethiopia.

***Determinants for technical inefficiency*:** The efficiency model was estimated in a two-step process, starting with the evaluation of the stochastic frontier production function to generate efficiency scores. Generated efficiency scores were then regressed on farmer's characteristics, institutional characteristics, and plot-specific characteristics. The estimated efficiency model was tested for multicollinearity using the variance inflation factor (VIF). There was no severe multicollinearity, as indicated by the predictors' mean VIF of 2.7, which is substantially within the acceptable range.

Table 3 presents the factors affecting the technical efficiency of sunflower smallholder farmers in the central zone corridor of Tanzania. The signs and significance of the estimated coefficients in the inefficiency model have important implications on the technical efficiency of smallholder farmers (Ng'Atigwa *et al*., 2022). A negative coefficient

reflects higher efficiency, leading to improved productivity, while a positive coefficient signals lower efficiency, resulting in decreased productivity. Seven of the twelve factors included in the inefficient model exhibited negative correlations and were significant determinants of technical efficiency in sunflower production. These factors included age, sex, education, group membership, credit access, extension visits and market access.

Age had a negative and highly significant impact at the 5% significance level. This suggests that each additional year in the age of household heads is associated with a 2.49% increase in the likelihood of achieving technical efficiency. It is believed that age can serve as a proxy for farming experience. The age of the household is directly related to agricultural experience and the capacity to carry out those demanding farming duties. Compared to younger farmers, older farmers are probably more experienced, competent and more skilled in growing sunflowers. This could be as a result of improved farm management techniques and developed superior command on resources. This result is supported by findings by Belete (2020) and Tumuri *et al*. (2024) who found a positive influence of age on technical efficiency among smallholder farmers in Ethiopia.

The coefficient of education level of household heads was estimated to be negative and statistically significant at a 1% level of significance. Results in Table 3 show that a one-year increase in the education of household heads is associated with a 5.83% increase in the likelihood of achieving technical efficiency in sunflower farming. This demonstrates that farmers with more years of formal education typically grow sunflowers more efficiently. This is likely attributed to their enhanced capacity to acquire technological knowledge,

Table 3. Maximum likelihood estimates of the Frontier mode.

Variable	Pooled sample		Kongwa district		Iramba district	
	coefficient	St.error	Coefficient	St.error	Coefficient	St.error
ln(Land)	0.04196***	0.0403	0.3476**	0.0244	1.4581***	0.2391
ln(Labor)	-0.0054	0.8560	-0.3231	0.0058	-0.1833	0.0014
ln(Seeds)	0.05133***	0.0226	0.0463**	0.0304	2.4047***	0.0825
ln(Fertilizer)	0.0357*	0.0198	0.1751***	0.0221	0.0218***	0.0071
$\ln(\text{Labor})^2$	-0.0145	0.0045	-0.0213	0.0056	0.0518*	0.0168
$\ln(\text{Fertilizer})^2$	-0.0284**	0.0017	0.0123***	0.0024	0.0314***	0.0034
$\ln(\text{Seeds})^2$	-0.0795	0.0078	-0.0605***	0.0107	-0.0716**	0.0414
ln(Land x labor)	0.05098	0.0151	0.0412	0.0114	0.3724***	0.0238
ln(Land x fertilizer)	0.00256	0.0024	0.0890***	0.0230	0.0014	0.0021
ln(Seeds x fertilizer)	0.00561**	0.0043	-0.0506**	0.0325	0.0323**	0.2152
Technical Inefficient model						
Age of household	-0.0249**	0.0064	-0.0065	0.0110	-0.0158	0.0074
Family size	0.0645	0.0446	0.0154	0.0568	0.0343	0.0461
Sex of household	-0.2580*	0.1020	-0.2202	0.1887	-0.2753	0.2452
Education level	-0.0583***	0.0410	-0.0657	0.0488	-0.0498	0.0384
Farming experience	-0.0211	0.0107	-0.0481	0.0175	-0.0314	0.0150
Land size	0.0153	0.0099	0.0119	0.0086	-0.0126	0.0331
Number of plots	0.0378	0.0384	0.0288	0.0385	0.0163	0.1569
Grp membership	-0.0404**	0.0345	-0.7044	0.4101	-0.0587	0.3186
Access to credit	-0.0347***	0.2701	-0.2174	0.3532	-0.5753	0.4174
Extension visits	-0.0498***	0.0783	-0.0723	0.1041	-0.0243	0.1090
Livestock (TLU)	-0.0793**	0.3440	0.6411	0.5603	-0.3473	0.2912
Off-farm income	-0.0264	0.0691	-0.3934	0.1458	-0.2716	0.0814
Sigma-v	0.3107	0.0361				
sigma-u	0.6963***	0.0507				
sigma2	0.5909	0.0653				
lambda	2.4227	0.0723				
Observations	371.00					
Wald-chi	21.16					
Prob > chi2	0.000					
VIF	2.70					
Mean TE	0.5963					

*, **, *** implies significant at 10%,5% and 1% probability level respectively

Source: Own computation (2023)

Table 4. Technical Efficiency levels and Productivity among farmers (n = 371).

Technical efficiency			Productivity		
TE range	**Frequency**	**Percentage**	**Yield kg/acre**	**Frequency**	**Percentage**
0.0 - 0.3	29	7.82	0.0 – 9000	309	83.3
0.3 - 0.6	130	35.04	1000 – 1900	59	15.9
0.6 - 0.9	211	56.87	2000 – 2900	3	0.8
0.9 - 1.0	1	0.27	3000 above	0	0.0
Total obsv	371	100.00		371	100.0
Mean	0.6055		Mean	671	
St deviation	0.1849		St deviation	457	
Minimum	0.1235		Minimum	67	
Maximum	0.9017		Maximum	1535	

Source: Field survey (2023)

enabling them to produce more efficiently closer the production frontier. Education enhances the managerial and technical skills of the farming households, which increases productivity by better allocation inputs. This finding is supported by several previous studies (Abdulai *et al*., 2018; Anang *et al*., 2024; Endalew *et al*., 2023; Ghimirea *et al*., 2023).

Farmer's group membership was found to be a positive and significant factor affecting the technical efficiency of sunflower production in the study area. The coefficient was 0.04041 and statistically significant at the 5% level. This implies that household heads who are members of farmer's associations or groups are 4.04% more likely to improve their technical efficiency. Participation in groups would give farmers more access to high-quality inputs, technical information, and knowledge of the production system that may add up to an increase in production. These findings support those of Ghimirea *et al*. (2023), who discovered that farmers' participation in cooperatives and groups improved the technical efficiency of lentil farmers by 2.67% in Nepal.

The findings also revealed that, access to credit had a positive and statistically significant effect on technical efficiency at the 1% level of significance. Table 3 indicates that farmers with access to credit are 3.5% more likely to achieve higher technical efficiency compared to those without access. Access to credit helps farming households overcome financial limitations. Removing these constraints enables farming household to apply necessary inputs and make effective management decisions, thereby improving efficiency. These finding aligns with previous researches (Anang *et al*., 2024; Bedasa & Tekalign, 2023; Belete, 2020).

The inefficiency model also revealed that extension visits has a significant and positive impact on technical efficiencies at 1% significance level. Findings from Table 3 indicates that one additional visit from an extension officer increases the likelihood of a sunflower farmer achieving higher technical efficiency by 4.9%. This suggests that consistent communication between the farming household and the extension agent enhances the flow of innovative ideas needed for improving sunflower productivity. Furthermore, the likelihood of a sunflower farmer being more technically efficient increases by 4.9% with one more visit by extension officer. This result is in line with the findings from previous studies in Tanzania and elsewhere (Belete, 2020; Lutonja, 2022; Ng'Atigwa *et al*., 2022; Tumuri *et al*., 2024).

The coefficient of livestock ownership for technical efficiency is positive and statistically significant at 5% level of significance. Positive and significant impact of livestock ownership on technical efficiency may due to multiple benefits of livestock. For example, livestock can provide power for tilling (such as oxen), manure to maintain soil fertility, and serve as a means of transportation. Additionally, livestock acts as a buffer against unforeseen risks from crop failure, offering both food and income for the entire household. Findings from Table 3 shows that technical efficiency of a farming household will increase by 7.9% for a unit increase in livestock herd. This result is in line with the results from previous studies (Anang *et al*., 2024; Bati & Haji, 2020; Belete, 2020; Tumuri *et al*., 2024).

***Levels of technical efficiency*:** The technical efficiency scale for each production unit included in the study show that the efficiency levels of the sunflower-producing units vary significantly. With a minimum of 12.35% and a maximum of 90.17%, farmers were able to produce at varying levels. On average, they achieved 60.6% of the potential output from a given combination of production inputs. The mean technical efficiency of 60.6% suggests that, on average, 39.4% more output could have been produced with the same level of inputs. This would have been possible if producers had used cost-minimizing techniques and best farming practices to operate on the most efficient frontier. Additionally, most sunflower farmers in the study (56.87%) attained technical efficiency levels ranging from 0.6 to 0.9. The highest efficiency level, achieved by just 0.2% of the farmers surveyed, ranged from 0.9 to 1.0. With an average productivity of 671 kg per acre, the majority (83.3%) of farmers had productivity levels ranging from 0 to 900 kg per acre. This indicates that most sunflower farmers in the study

area are not achieving their full potential of 2 to 3 tons per acre (Kombe *et al*., 2017). This suggests that there is a considerable gap between the actual and potential sunflower productivity in the study area. These yield gaps can be attributed to differences in the technology used, variations in the production environment, and the efficiency of the production process.

***Conclusion*:** This study assessed the technical efficiency of smallholder sunflower farmers in Tanzania's central zone corridor of Tanzania using the trans log production function approach. The findings revealed considerable variation in efficiency levels among farmers, with an average technical efficiency of 60.6% indicating significant potential for improving productivity with existing inputs. The results also highlighted that only 0.2% of farmers operated close to the production frontier, while the majority achieved yields far below the potential of 2 to 3 tons per acre. Key determinants of technical efficiency included education level, extension services, livestock ownership, access to credit and group membership. Enhancing these factors through targeted policy interventions and capacity-building initiatives can significantly improve productivity in the sunflower sector. Ultimately, improving technical efficiency is crucial for increasing sunflower productivity and improving the livelihoods of smallholder farmers in the region.

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